

Description

Method and arrangement for determination of the rotation speed of a direct-current motor

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The present invention relates to a method for determination of the rotation speed of a direct-current motor, to an arrangement for determination of the rotation speed of a direct-current motor, and to the use of an arrangement such as this in a fan and a pump.

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The rotation speed of motors can be determined using various methods. In this case, in principle, a distinction is drawn between those methods in which additional sensors or transmitters are used, for example using Hall elements or light barriers, to produce a signal which is proportional to the rotation speed, and between those methods in which the motor current or the motor voltage is evaluated in order to produce a signal which is proportional to the rotation speed.

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By way of example, in the document DE 1 673 364, the rotation speed is determined by evaluation of changes over time in the motor current, caused by current changes from one commutator laminate to the next, using pulse-shape stages and measurement appliances, for example rotating coil instruments.

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The document DD 254 254 A1 likewise discloses a circuit arrangement for production of a signal which is proportional to the rotation speed in direct-current commutator motors, in which voltage-controlled high-pass, low-pass and narrowband-pass filters are provided for signal evaluation.

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The documents DE 199 15 875 A1 and DE 199 15 877 A1 disclose methods and apparatuses for measurement of the

rotation speed of a direct-current commutator motor, in which the rotation speed evaluation is carried out by means of frequency analysis and time synchronization, respectively.

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In the document DE 197 29 238 C1, electromechanical motor equations and a motor model which operates in parallel with the motor are used to extrapolate a state estimate of the probable instantaneous rotation speed from the motor voltage or from the motor current.

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All of the described methods and apparatuses have the common characteristics that they do not require any additional sensors or transmitters in order to determine the rotation speed with the rotation speed advantageously being determined, instead of this, from the motor voltage or the motor current. Relatively complex apparatuses and/or computation-intensive methods are used for this purpose. Furthermore, some of the methods and apparatuses are designed and are suitable only for specific motor types. Some of the described methods are additionally not suitable for following changes in the motor parameters over time.

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One object of the present invention is to specify an arrangement and a method for determination of the rotation speed of a direct-current motor, which allows continuous measurement of the rotation speed and can, at the same time, be implemented with little complexity.

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According to the invention, the object with respect to the arrangement is achieved by an arrangement for determination of the rotation speed of a direct-current motor, comprising

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- a signal input for supplying a signal which is derived from the motor voltage or the motor current of the direct-current motor,

- an analog/digital converter having an input which is coupled to the signal input and having an output for production of a sequence of sample values,
- 5 - a first averager for the sequence of sample values, which is coupled to the output of the analog/digital converter,
- a second averager for the sequence of sample values, which is coupled to the output of the
10 analog/digital converter, with the first and the second averaging processes each being related to a different number of sample values,
- a comparator, which is connected to the first and to the second averager and produces a mathematical
15 sign at its output, as a function of the comparison result, and
- a computation unit which is coupled to the comparator, for determination of the rotation
20 speed of the direct-current motor as a function of the number of sample values between mathematical-sign changes.

Advantageous developments of the arrangement can be found in the dependent claims.

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A digital signal processor can thus preferably be provided which comprises the first averager, the second averager, the comparator and the computation unit.

30 A current measurement resistor is furthermore preferably provided, and forms the signal input of the arrangement.

A resistor which is arranged in series with the motor
35 can preferably also be provided. In this case, the motor advantageously does not need to be disconnected from a supply voltage source while carrying out the rotation-speed measurement. The motor need not be

switched to a generator mode in order to carry out the rotation-speed measurement.

5 The current measurement resistor can be arranged at any desired point in series with the motor, that is to say by way of example at the motor positive pole or at the motor negative pole.

10 It is possible to provide a DC voltage amplifier which couples the signal input to the input of the analog/digital converter.

15 The DC voltage difference across the current measurement resistor can preferably be amplified by means of a DC voltage amplifier, whose input stage is preferably floating, and can be produced as a time-continuous, ground-related signal at the output of the amplifier.

20 The direct current motor is preferably a direct-current commutator motor.

25 In the case of a motor with brushes, the voltage difference across the current measurement resistor will also have current components which vary over time, in addition to a direct-current component for feeding the motor. These current components which vary over time are caused inter alia by the transfer of the current in the sliding contacts from one motor segment to the next, and are therefore proportional to the rotation speed.

35 The two averagers produce two mean values, which can be updated continuously by the sequence of sample values. The respective number of sample values from which the two different mean values are formed can be defined in advance as a function of the motor type, or by means of a small number of initial trials, in a simple manner.

The number of sample values between the mathematical-sign changes of the recurring comparison results of the two mean values is multiplied by the time period between the individual samples. This time period is predetermined by the sampling rate of the analog/digital converter. By way of example, half the period duration of the electrical contact changes in the motor is calculated by the multiplication. The instantaneous motor rotation speed can in turn be determined from this in a simple manner.

In order to calculate the rotation speed, the number of sample values between immediately successive mathematical-sign changes can be determined, and can be multiplied by the time period between the individual samples. Alternatively, however, it is also in each case possible, for example, to multiply the time period which has passed between mathematical-sign changes in the same sense, by multiplication of the number of sample values between these mathematical-sign changes of the recurring comparison results by the time period between the individual samples, and to use this to calculate the rotation speed. In addition to the time period between mathematical-sign changes, the actual rotation speed of the motor is also dependent on the number of contact changes or commutation operations during one revolution of the motor.

In the proposed principle, changes in the motor voltage or motor current over time are recorded. No additional sensors are required for this purpose. In fact, the principle can be implemented with little complexity, preferably using integrated circuit technology. Only one analog/digital converter and a microcontroller or other means for digital signal processing are provided, which form mean values, and carry out comparison and rotation-speed calculation operations.

With regard to the method, the object is achieved by a method for determination of the rotation speed of a direct current motor, having the following steps:

- 5 - detection of the motor voltage or of the motor current, or of a signal which is derived from the motor voltage or motor current of the direct-current motor,
- sampling of the signal and production of a
10 sequence of sample values,
- formation of a first mean value of a first number of sample values,
- formation of a second mean value of a second number of sample values,
- 15 - comparison of the first mean value with the second mean value, and production of a mathematical sign of the result,
- calculation of the rotation speed as a function of the number of sample values between mathematical-
20 sign changes.

The rotation speed is preferably calculated by carrying out a multiplication of the number of sample values between mathematical-sign changes of the recurring
25 comparison results by the time period between the individual samples, which is predetermined by the sampling rate at which the signal is sampled.

In this case, the known relationships between the
30 period duration, the rotation speed and the number of contact changes during one revolution can be taken into account.

Preferred developments of the described method are
35 specified in the dependent claims.

The first number of sample values is thus preferably greater than the second number of sample values.

The first and the second mean values are preferably updated continuously using the incoming sample values.

- 5 The always updated mean values are preferably compared with one another continuously.

The respective number of sample values formed between two mathematical-sign changes of the recurring
10 comparison results is preferably multiplied in the computation unit by the time between the individual sample values, thus calculating half the period duration of the electrical contact changes in the motor, from which the rotation speed of the motor can
15 in turn be calculated.

The rotation speed is preferably determined as a function of the time which passes between two electrical contact changes between the commutator
20 laminates and the sliding contact or the contact brushes.

The rotation speed is preferably measured continuously using the proposed method. One advantage in this case
25 is that no switching is required from motor operation to a generator mode.

In the course of a calibration process, an extensive series of measurements can advantageously be recorded
30 during normal motor operation in order to derive fundamental information about the useful and interference spectra of the signal, and signal conditioning can be carried out, by means of statistical signal analysis. A signal model which is
35 matched to the interference spectrum which occurs as a function of operation can then be determined for the signal form of the AC voltage produced by the motor itself. The signal model with the useful spectrum,

which can be configured with respect to the time profiles and/or signal frequencies, can in this case be adapted for the particular motor operating situation.

- 5 One additional advantage of the method is that the described method can be used in the event of major changes in the operating state of the motor, such as the current form, the dynamic range of the signal, the rotation speed, the load conditions, the interference
10 spectrum of the pulse-width modulated control, etc. However, the method is also suitable for major differences in motor-specific characteristics such as motor types, running characteristics, aging-dependent changes in the motor characteristic, etc. Typical
15 characteristic variables may in this case advantageously be obtained without any complex signal transformation, that is to say without using fast Fourier transformation FFT or the like.
- 20 Yet another advantage of the proposed method is that the functionality can be provided entirely in software, specifically in a simple microcontroller, and can thus be flexibly matched to different applications. Since no additional hardware whatsoever is required, this
25 results in a highly cost-effective system solution.

The invention will be explained in more detail in the following text using one exemplary embodiment and with reference to the figure, in which:

- 30 the figure shows one exemplary embodiment of the proposed principle, on the basis of a block diagram.

- The figure shows an arrangement for determination of
35 the rotation speed of a direct-current motor 1. The direct-current motor 1 is connected to a voltage source 2, for its electrical supply. The voltage source 2 is designed such that it can be connected and

disconnected, and produces a variable signal. A series resistor 3 is connected to the voltage source 2, in series with the direct-current motor 1. The series resistor 3 is in the form of a measurement resistor, that is to say a shunt. The two connections of the measurement resistor 3 are connected to inputs of a DC amplifier 4. The amplifier 4 is in the form of a DC voltage amplifier and has a floating input stage. The output of the DC voltage amplifier 4, at which a ground-related signal is produced, is connected to the input of an analog/digital converter 5. The analog/digital converter 5 is designed to emit a sequence of sample values at its output. The output of the analog/digital converter 5 is connected to the input of a microcontroller 6. The microcontroller 6 comprises a first averager 61 and a second averager 62, the inputs of both of which are coupled to the output of the analog/digital converter 5. The outputs of the two averagers 61, 62 are connected to a comparator 63, whose output is in turn coupled to a computation unit 64. The computation unit 64 produces a signal which is proportional to the rotation speed at its output. A further input of the computation unit 64 is coupled to the output of the analog/digital converter 5 and to a connection for supplying the sampling rate of the analog/digital converter 5. The computation unit 64 is designed to multiply the number of sampled individual values between two mathematical-sign changes by the time between the individual sampling processes. This value corresponds to half the period duration of the electrical contact changes in the motor 1. For this purpose, the comparator 63 in each case produces a mathematical sign for the comparison between the mean values of the first and of the second averager 61, 62.

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According to the proposed method for continuous period duration measurement, the time is measured which passes between electrical contact changes between the

individual commutator laminates and the sliding contact in a rotating commutator motor 1. This is achieved by supplying an analog/digital converter 5 with the electrical changes in the physical characteristics of the motor 1 which are caused in consequence, and are present at its electrical connections, in particular across the resistor 3, as an analog physical variable. The analog/digital converter 5 samples these changes using a predetermined time pattern within a predetermined time window, and emits the sampled instantaneous values as a series of digital numerical values. A first mean value is calculated from the digital numerical values in a first averager 61, from a relatively large number of sample values, and this mean value is continuously updated by means of incoming numerical values. Furthermore, a second averaging process is carried out from the digital sample values by calculating the mean value from a smaller number of individual values in comparison to the first mean value. The second mean value is also updated continuously by further incoming sample values. The comparator 63 repeatedly compares the first mean value and the second mean value. The mathematical sign of the comparison is formed during this process. The number of sample values between the mathematical-sign changes in the recurring comparison results is multiplied by the time period between the individual samples. This time period is predetermined by the sampling rate of the analog/digital converter. Half the period duration of the electrical contact changes in the motor 1 is calculated by the multiplication.

The number of sample values between immediately successive mathematical-sign changes can be determined and can be multiplied by the time period between the individual samples, in order to calculate the rotation speed. Alternatively, however, it is also in each case possible, for example, to multiply the time period

which has passed between mathematical-sign changes in the same sense by multiplication of the number of sample values between these mathematical-sign changes in the recurring comparison results by the time period
5 between the individual samples, and to use this to calculate the rotation speed. The actual rotation speed of the motor depends not only on the time period between mathematical-sign changes but also on the number of contact changes or commutations during one
10 revolution of the motor.

According to the proposed principle, a particularly cost-effective system solution is provided by means of which the rotation speed of a motor can be measured
15 without additional apparatuses, and in consequence with low costs.

In particular, the motor rotation speed that is obtained can be used for regulation of the motor
20 rotation speed.

The required apparatuses such as a DC amplifier 4, an analog/digital converter 5 and a microcontroller 6 are necessarily provided in any case in a motor control
25 system, even when no rotation-speed measurement and/or no rotation-speed regulation are/is carried out. The present method for rotation-speed measurement can thus be implemented with particularly little complexity, and cost-effectively.

30 In the present case, the time-continuous DC voltage across a resistor 3 which is arranged in series with the motor 1 is used as the signal to be evaluated for the rotation-speed measurement. The motor 1 operates in
35 the normal operating mode all the time, and also need neither be disconnected from the supply voltage source nor need be operated in a generator mode while carrying out the rotation-speed measurement.

The measurement resistor 3 in the present case is arranged at the motor negative pole, the so-called low side, but can alternatively also be arranged at the
5 motor positive pole, the so-called high side.

The motor current and thus the voltage difference across the current measurement resistor 3, as well, can also have current components which vary over time in
10 addition to the direct-current component for feeding the motor, for example in the case of a motor with brushes, which current components which vary over time are caused by the current transfer between the sliding contacts, for example carbon brushes, from one motor
15 segment to the next, and are therefore proportional to the rotation speed.

The DC voltage difference across the measurement resistor 3 is amplified by the DC voltage amplifier 4
20 with a floating input stage, and is produced as a time-continuous, ground-related signal at the output of the amplifier 4. The DC voltage produced in this way is supplied to the input of an analog/digital converter, and is converted to a sequence of digital measured
25 values at a sufficiently high sampling rate. The present method is used to determine the rotation speed of the motor from the digital sample values, in the digital signal processor. In this case, the method is designed such that it requires a minimal amount of
30 computation power and a particularly small amount of memory. In particular, the described method can be implemented in a simple form using 8-bit microprocessors.

35 In the course of a calibration process, an extensive series of measurements can advantageously be recorded during normal motor operation, in order to derive fundamental information about the useful and

interference spectra of the signal, and to carry out signal conditioning, by means of statistical signal analysis. A signal model, which is matched to the interference spectrum which occurs as a function of operation, for the signal form of the AC voltage which is produced by the motor itself can then be determined. The signal model with the useful spectrum, which can be configured with respect to the time profiles and/or signal frequencies, can in this case be adapted for the particular motor operating situation.

One additional advantage of the method is that the described method can be used in the event of major changes in the operating state of the motor, such as the current form, the dynamic range of the signal, the rotation speed, the load conditions, the interference spectrum of the pulse-width-modulated control, etc. However, the method is also suitable for major differences in motor-specific characteristics such as motor types, running characteristics, aging-dependent changes in the motor characteristic, etc. Typical characteristic variables can in this case advantageously be obtained without complex signal transformation, that is to say without using a fast Fourier transformation FFT or the like.

Yet another advantage of the proposed method is that the functionality can be provided entirely in software, specifically in the microcontroller 6, and can thus be flexibly matched to different applications. Since no additional hardware whatsoever is required, this results in a highly cost-effective system solution.

Figure description

1	Motor
2	Voltage source
3	Measurement resistor
4	DC voltage amplifier
5	Analog/digital converter
6	Microcontroller
61	Averager
62	Averager
63	Comparator
64	Computation unit